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(54) A method for geo-registration of imported bit-mapped spatial data.

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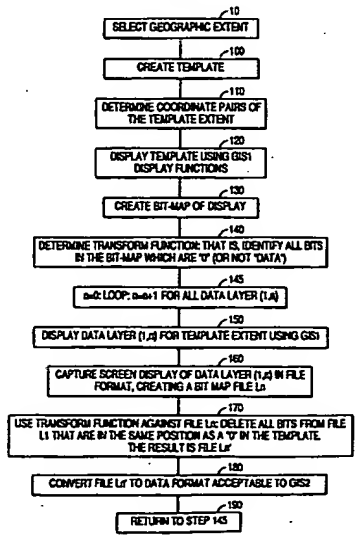
FIG. 1



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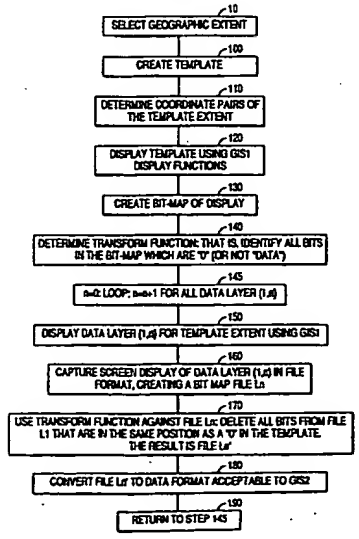

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FIELD OF INVENTION

The present invention relates to computer aided geographic information systems (GIS). More particularly, this invention relates to an improved method of converting data from one GIS to another, maintaining a consistent system of georeferencing.

BACKGROUND OF THE INVENTION

A geographic information system is an information system designed to work with data referenced by spatial or geographic coordinates. For example, on a very basic level, a contour map of an area of land (that is, a map in which contour lines indicate the elevations at specific geographic points) could be considered a GIS. If, to the contour map, we added a street map, a sewer map, and an aerial photograph, then we would have a GIS composed of four data sets: each set being referred to as a data layer or data plane.

In an automated GIS, the data layers will be stored in a data base system and a set of tools will be included to enter, manipulate and analyze the data, and then display the result either on a screen or as hardcopy printout.

To create an automated GIS, it is necessary to first identify and gather data. Typical sources of such data are municipal maps, government survey maps, aerial photographs and other publicly available data sources. The data must be extracted from these sources and then be manipulated so that it may be entered into the GIS. In addition, the data must be georegistered or georeferenced. That is, the spatial data must be referenced to a coordinate system such as Universal Transverse Mercator, State Plane, or Latitude/Longitude.

The geo-registration process is mathematically as follows:

$$x = f_1(X,Y)$$
$$y = f_2(X,Y)$$

where

- (x,y) = distorted coordinates in some coordinate system,
- (X,Y) = correct coordinates in a selected reference grid
- f_1, f_2 = transformation functions

In its simplest form, where the distorted coordinates are taken from a scale drawing and the selected reference grid is a flat surface marked by latitude and longitude, the transformation functions are linear equations of the type: $x = AX + BY + C$, where A, B and C are constants. In the case of aerial photographs, where the intent is to represent the curved earth surface on a flat map, and where the angle of the photograph, as well as the photographs representation of a curved surface in a two dimensional plane must be taken into account, the transformations are considerably more complex but are well known in the art.

The standard method by which data is georegistered against selected reference coordinates (i.e. of identifying the required transformation functions) can be described as follows:

1. select a point from the spatial data available (distorted coordinate system) and determine the equivalent point in the selected reference grid;
2. express both selected points in terms of pairs of coordinates and compute the transformation function which reflects the relationship between the pairs;
3. choose another point and repeat steps 1 and 2.

Repeating the process for all points in the spatial data set would be prohibitively costly in both time and effort. Accordingly, the process is repeated only for a selected sample of points. The method by which the points are chosen (the sampling methodology) can be taken from a variety of well-known techniques such as nearest neighbor, bilinear, or cubic convolution.

It is not uncommon for the "true" transformation function to vary over the area of interest. For example, in an aerial photograph, the curvature of the earth results in a different mapping of points to the two dimensional picture. Accordingly, the "true" transformation function varies depending on the distance from the observation point to the pictured surface. As another example, consider a diagram of water mains. If the purpose of the diagram was to indicate the points of interconnection, then the representation of the mains between such interconnection points would not necessarily be consistant in the sense that there would likely not be a constant ratio of mapped lines to the physical distance between points. The "true" transformation function to georeference such a diagram would consist of a collection of linear functions, none of which were necessarily related to any other.

Where the "true" transformation varies over different parts of a map, the transformation calculated from only a subset of points may have certain inaccuracies. This will result in distortions when the calculated transformation function is used to georeference the entire set of spacial data points.

Various schemes for automating the process of georeferencing exist in the art. Most of the techniques focus on reducing the distortion by choosing a large number of coordinate pairs (i.e. rubbersheeting techniques.) The current state of the art is described in the book Remote Sensing and Image interpretation, Lillesand and Kiefer, Second edition, 1987, Chapter 10, Section 10.2.

Step 170 consists of using the Transform Template against FILE L1. That is, the transform information is used to compress FILE L1 by dropping all the bits in the positions which correspond to the zero bits in Step 140. The output of this step is the transformed file, FILE L1'.

Step 180 consists of converting FILE L1' to ASCII data using programs such as GRASS's "r.in.ascii" command and the template extent identified in Step 110.

As can be seen from FIG. 2, Step 190, Steps 150 through 180 are repeated for Data Layer (1,2) and Data Layer (1,3), creating files File L2' and File L3'. All three transformed files (in this example, FILE L1', FILE L2' and FILE L3') are imported to GIS2.

As will be clear to those skilled in the art, an important step in the invention and improvement over the prior art is the step of recognizing that a template map can be created and exploited for all succeeding coverages or layers to be transferred. Since the transform function is created only once, for all points, by creating the function for the template map and then applying that function to all subsequent map layers, all subsequent map layers can be imported without re-selecting coordinate pairs, or recomputing transformation functions. This results in perfectly co-registered map layers in the second GIS, as well as correct geo-registration to a coordinate system. In addition, if a distortion is introduced in the creation of the transformation function, the distortion is carried systematically throughout each of the data layer transforms. Systematic errors to those skilled in the art can either be easily corrected or, for some applications, even ignored.

As discussed, FIG. 3 is an example of a portion of the instructions which can provide the function corresponding to Step 140 of FIG.1, namely, to convert the bit-map of the template to a transform function. For the embodiment under discussion, a program with the function of the pseudo code shown in FIG. 3 was written in the C programming language as described in the publication "The C Programming Language" by Brian W. Kernighan and Dennis M. Ritchie, 1978, and also "X Window Systems Programming and Applications with Xt" by Douglas A. Young, 1989. Programs with this function can be written in any other conventional program language, as, for example, Fortran.

It is within the scope of the invention, that the order of the steps of the instructions in FIG. 3 can be altered, or other steps added, without changing the fundamental nature of the invention. It is similarly within the scope of the invention, that the order of the steps of FIG. 1 can be altered, or other steps added (as for example, providing for error routines), without changing the fundamental nature of the invention.

In as much as this invention outlines a method for georegistering the bit-mapped display output of one GIS to be provided as input to another GIS, the technique described herein solves several important user requirements. For example, in the absence of a common data exchange format, this invention gives users of GIS products the ability to preserve a significant investment in their data (typically around 80% of total system implementation costs).

The invention has been described in reference to specific embodiments. Although a specific embodiment of the invention has been disclosed, it will be understood by those having skill in the art that other embodiments, variations and modifications to the herein described specific embodiment can be made without departing from the spirit and scope of the invention. For example, it will be clear to those skilled in the art that the invention may also be used to map one or more data layers from GIS1 and one or more data layers from GIS2 into GIS3. Accordingly, it is not intended that this invention should be limited except as indicated by the accompanying claims.

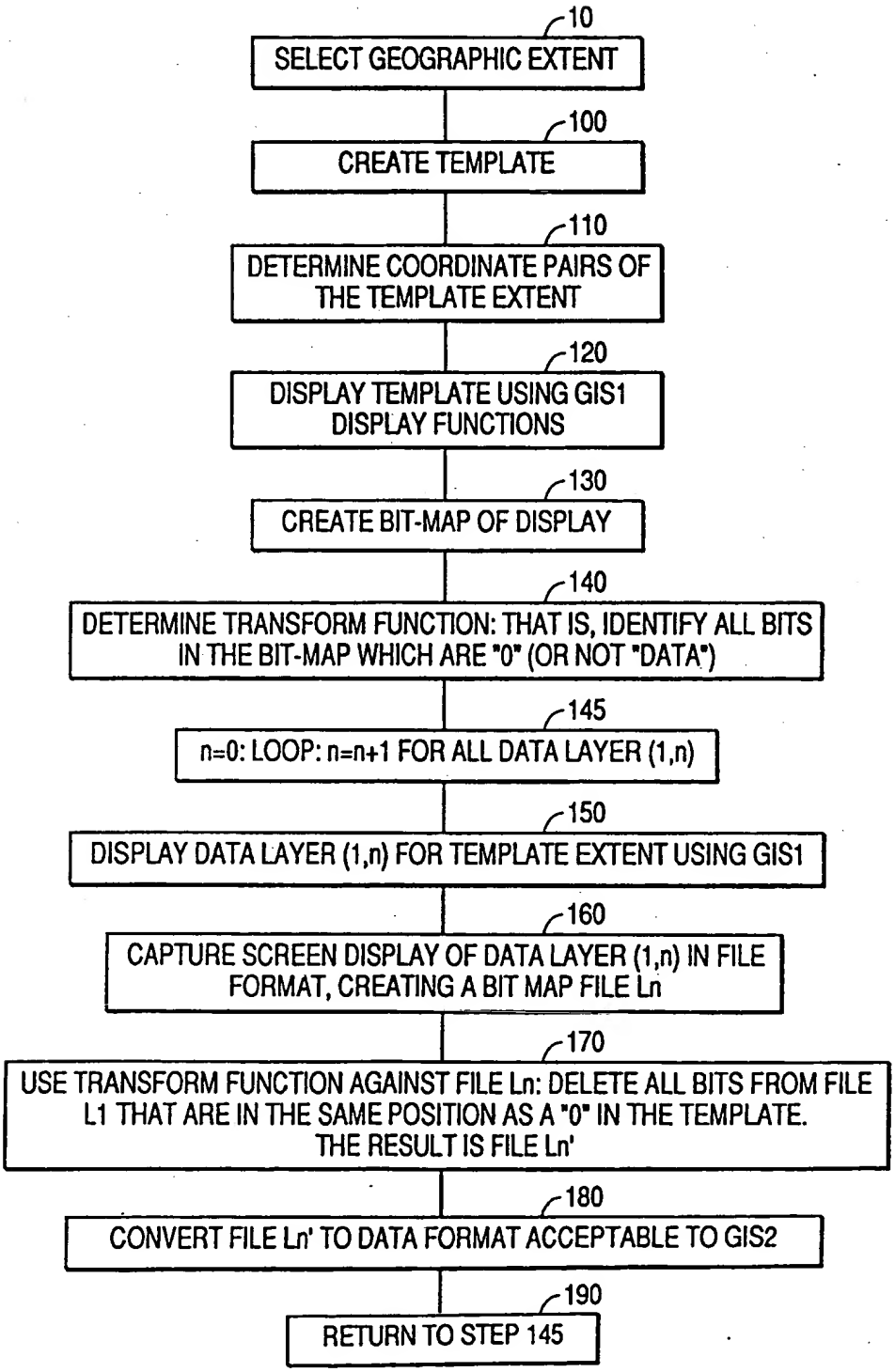
Claims

1. In a graphic computer system including a display and a plural-ity of geographic information systems (GIS), each of said GIS containing a plurality of data layers, each data layer comprised of georeferenced data, a method for transferring georegistering data between a plurality of GIS while preserving georeferencing and maximizing accuracy, said method comprising the steps of:

   a. selecting a geographic area, said area's boundary comprised of a plurality of line segments, each of said line segment being adjacent to two other of said line segments, and each line segment having two end points, each of said end point being shared with one of said adjacent line segments. Each of said geographic area end points having a coordinate pair associated with it, said coordinate pair identifying the geographic location of said end point.

   b. creating a template, comprising a two-dimensional polygon whose boundary is comprised of a plurality of line segments, each of said line segment being adjacent to two other of said line segments, and each line segment having two end points, each of said end point being shared with one of said adjacent line segments. Said template being congruent in shape and area to said geographic area and each of said template end

FIG. 1


10
SELECT GEOGRAPHIC EXTENT
100
CREATE TEMPLATE
110
DETERMINE COORDINATE PAIRS OF THE TEMPLATE EXTENT
120
DISPLAY TEMPLATE USING GIS1 DISPLAY FUNCTIONS
130
CREATE BIT-MAP OF DISPLAY
140
DETERMINE TRANSFORM FUNCTION: THAT IS, IDENTIFY ALL BITS IN THE BIT-MAP WHICH ARE "0" (OR NOT "DATA")
145
n=0: LOOP: n=n+1 FOR ALL DATA LAYER (1,n)
150
DISPLAY DATA LAYER (1,n) FOR TEMPLATE EXTENT USING GIS1
160
CAPTURE SCREEN DISPLAY OF DATA LAYER (1,n) IN FILE FORMAT, CREATING A BIT MAP FILE Ln
170
USE TRANSFORM FUNCTION AGAINST FILE Ln: DELETE ALL BITS FROM FILE L1 THAT ARE IN THE SAME POSITION AS A "0" IN THE TEMPLATE. THE RESULT IS FILE Ln'
180
CONVERT FILE Ln' TO DATA FORMAT ACCEPTABLE TO GIS2
190
RETURN TO STEP 145